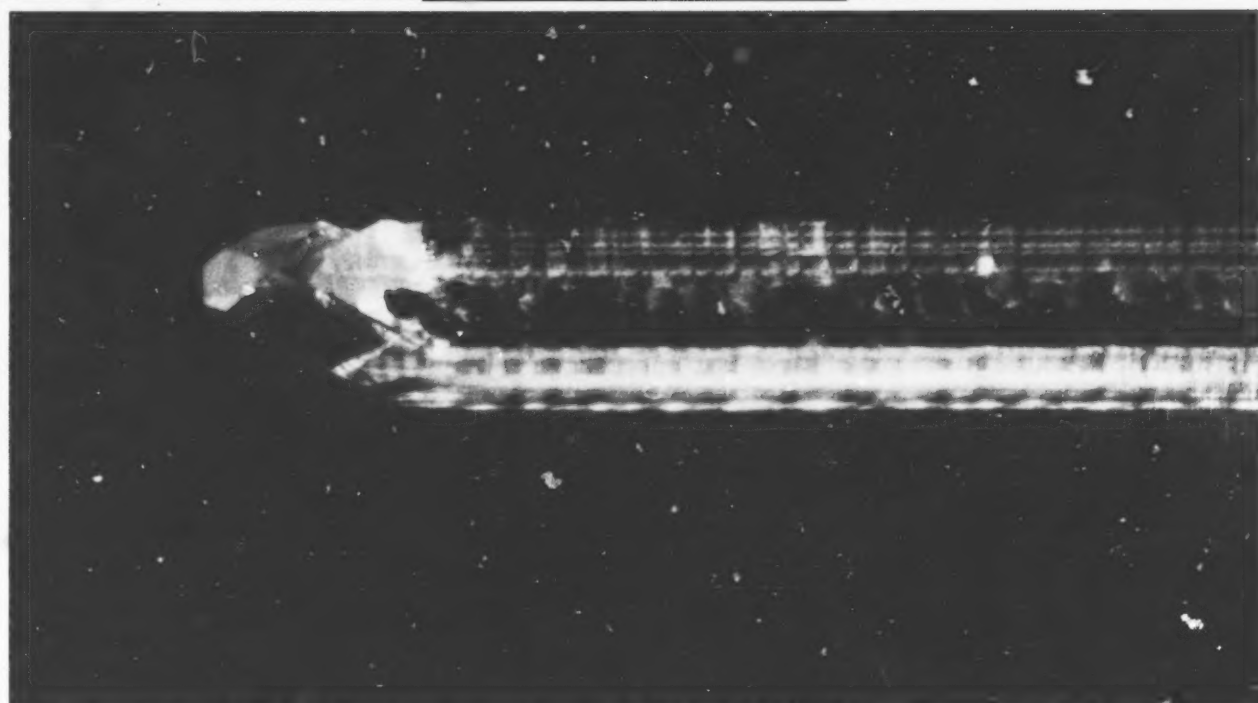


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MINERALS YEARBOOK



QUARTZ CRYSTAL

By Joyce A. Ober

1989

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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QUARTZ CRYSTAL



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Secretary



BUREAU
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Director

August 1990

Contents

Domestic Data Coverage	1
Legislation and Government Program	1
Strategic Considerations	2
Production	2
Consumption and Uses	2
Stocks	3
Prices	3
Foreign Trade	3
Outlook	3

Tables

Table 1.—Salient U.S. Electronic- and Optical-Grade Quartz Crystal Statistics	1
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COVER PHOTO:

Cultured quartz crystal has replaced natural quartz crystal in nearly all applications. As-grown crystal (shown here) is cut into crystal blanks and set into devices according to specifications.

*For comments or further information, please contact
The Branch of Industrial Minerals
The Division of Mineral Commodities
Bureau of Mines
2401 E St., NW, MS 5209
Washington, DC 20241-0001
Telephone: (202) 634-1177
FAX: (202) 634-4091*

QUARTZ CRYSTAL

By Joyce A. Ober

Mrs. Ober, a physical scientist with 12 years industry and Bureau of Mines experience, has been the commodity specialist for quartz crystal since 1986. Domestic survey data were prepared by Maureen Nash, mineral data assistant.

Cultured quartz crystal production and consumption increased in 1989 for the third consecutive year, and consumption of domestic lascas as feedstock for cultured quartz crystal increased also. The single domestic producer of lascas, the raw material from which cultured quartz crystal is produced, operated its mine to supply material to consumers. Demand for specimen-quality natural quartz continued; quartz crystal for this application is discussed in the Gem Stones chapter.

Electronic-grade quartz crystal is single-crystal silica that is free from all visible defects and has piezoelectric properties that permit its use in electronic circuits for accurate frequency control, timing, and filtration. These uses generate practically all the demand for electronic-grade quartz crystal.

Natural electronic-grade quartz crystal was the leading form of quartz until 1971 when cultured quartz crystal took the lead. Cultured (synthetic) quartz has replaced natural crystal in practically all applications. In 1989, synthetic quartz crystal producers consumed about 570,000 kilograms of lascas in their production and less than 500 kilograms of natural quartz crystal found application in electronic devices.

DOMESTIC DATA COVERAGE

The Bureau of Mines collected domestic production and consumption data for quartz crystal through a voluntary survey of U.S. operations. Seven companies responded to the canvass for the production of cultured quartz crystal, and the six active operations represented 100% of total production shown in table 1. Of the 34 operations canvassed concerning consumption of quartz crystal, 32 re-

sponded, 7 of which did not consume quartz crystal in 1989. These companies represented nearly 100% of total consumption, also shown in table 1. Consumption for the nonrespondents was estimated using reported prior-year consumption levels.

The metric system is the official system of measurement of most countries. The Bureau of Mines, in an effort to provide statistical data on quartz crystal that are consistent with international usage, will henceforth report data in kilo-

grams and metric tons unless otherwise noted.

LEGISLATION AND GOVERNMENT PROGRAMS

The National Defense Stockpile contained about 764,000 kilograms of natural quartz crystal, valued at \$10 million. This quantity represented an excess of about 492,000 kilograms

TABLE 1
SALIENT U.S. ELECTRONIC- AND OPTICAL-GRADE
QUARTZ CRYSTAL STATISTICS

(Thousand kilograms and thousand dollars)

	1985	1986	1987	1988	1989
Production:					
Mine ^{e 1}	454	544	—	272	454
Cultured	258	238	381	389	464
Exports:					
Natural: ²					
Quantity	27	34	63	43	NA
Value	\$290	\$411	\$708	\$431	NA
Cultured: ²					
Quantity	84	147	203	189	57
Value	\$3,723	\$5,686	\$6,954	\$7,162	\$2,600
Lascas:					
Quantity	^e 363	—	—	—	—
Imports of lascas:³					
Quantity	78	24	66	98	NA
Value	\$99	\$51	\$157	\$180	NA
Consumption:					
Natural (electronic- and optical-grade)	3	1	(⁴)	2	(⁴)
Cultured (lumbered)	20	20	25	28	17
Cultured (as grown)	102	194	250	293	344
Total	125	215	275	323	361

^e Estimated. NA Not available.

¹ Excludes lascas produced for specimen and jewelry material uses.

² Bureau of the Census as adjusted by the Bureau of Mines.

³ Bureau of the Census.

⁴ Less than 1/2 unit.

above the goal set for the stockpile. During the year, quartz crystal stockpile sales amounted to about 74,800 kilograms at \$368,000 to support the ferroalloys upgrading project. These were the first sales since 1985. The stockpile material, which primarily consists of large natural crystals, could be absorbed by the specimen and gem material industry. Very little, if any, of the material would be consumed in the same applications as synthetic quartz crystal.

STRATEGIC CONSIDERATIONS

Natural electronic-grade quartz crystal was initially designated after World War II as a strategic and critical material. At the time of U.S. stockpile acquisition, cultured quartz crystal was not commercially available. With the changing patterns of quartz consumption, the Federal Emergency Management Agency asked the National Materials Advisory Board to assess the requirements and related trends for stockpiling quartz. The final report was published in early 1985 and recommended changes in stockpile goals to reflect the declining dependence on natural quartz crystal.¹ Near yearend 1989, the President received authorization from Congress to further reduce the stockpile goal from about 272,000 kilograms to about 110,000 kilograms of quartz crystal.²

The National Defense Stockpile contains natural quartz in several weight classes and grades, including about 13,000 kilograms of material consisting of individual crystals weighing more than 10,000 grams each. Some of the individual quartz pieces in this weight class are suitable for generating mother seeds for cultured quartz crystal production. These large pieces were acquired from Brazil because similar materials were not available from a domestic source.³

PRODUCTION

Coleman Quartz Inc., Jessieville, AR, the only domestic company known to produce lascas, supplied the feed mate-

rial for cultured quartz crystal from mine production. Coleman mined only during the summer months, but processed lascas yearround. Lascas was mined, crushed, and sized. Crushed and sized material was transported to the processing plant where operators rinsed it in oxalic acid and then in deionized water to remove external contaminants. Finally, hand sorting, drying, and examination on a light table completed the necessary processing. The material was then shipped to cultured quartz crystal producers in 45-kilogram (100-pound) bags.

Production of cultured quartz crystal increased nearly 20% in 1989. Six companies were active. The two largest producers, Sawyer Research Products Inc. of Eastlake, OH, and Thermo Dynamics Corp. of Merriam, KS, were independent growers that produced crystal bars for domestic and foreign consumers in the crystal device fabrication industry. Motorola Inc. of Chicago, IL, produced quartz crystal for both internal consumption and the domestic device fabrication industry. P. R. Hoffman Material Processing Co. of Carlisle, PA, also reported outside sales. Bliley Electric Co. of Erie, PA, produced only for internal consumption. Electro Dynamics Corp. of Overland Park, KS, sold the quartz-crystal-growing portion of their operation to Thermo Dynamics in February 1989. Electro Dynamics continued to process synthetic quartz crystal.

These companies produced cultured quartz crystal using a hydrothermal process in large pressure vessels, known as autoclaves. Seed crystals, very thin crystals cut to exact dimensions, were mounted on racks and suspended in the upper growth region of the vessel. Lascas was loaded in an open-mesh wire basket that was placed in the bottom of the autoclave.

A solution of sodium hydroxide or sodium carbonate (the mineralizer), with additives such as lithium salts, and deionized or distilled water was used to fill the vessel to 75% to 85% of its volume. The bottom half of the growing vessel was heated to temperatures averaging between 350°C to 400°C; the temperature of the top portion is maintained at 10°C to 50°C less. At these temperatures, the solution expands and creates an internal pressure in the vessel between 10,000 and 30,000 psi. Under these conditions the lascas dissolves to

create a solution saturated with silica.

Through convection, the saturated solution transports dissolved silica to the cooler upper half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top half of the autoclave. The process continues until the growing crystals reach their desired size. The process may take 30 to 60 days, and sometimes even longer.

The processing of quartz crystals into various end uses is the same whether natural or cultured crystal is used. Before cutting, crystals are examined for physical defects. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness; the electrodes are attached; and are mounted in suitable holders. The final assembly, called a quartz crystal unit, is ready for insertion into an electronic circuit.

CONSUMPTION AND USES

Consumption of lascas by the six domestic quartz crystal producers increased about 27%, from 451,000 kilograms in 1988 to 572,000 kilograms in 1989. The 25 active device-fabricating companies in 9 States consumed 12% more quartz crystal in 1989 than in 1988. Of these companies, 24 consumed only cultured quartz crystal. One company consumed only natural quartz crystal.

Lascas and quartz crystal were used in piezoelectric, optical, and glass industries. The piezoelectric effect is achieved when a suitable electrical signal is applied to a quartz wafer or blank with appropriate electroding and the wafer then vibrates mechanically throughout the bulk of the material at a characteristic natural resonance frequency. The quartz resonators are uniquely suitable for military-aerospace and commercial bandpass filter applications that require very high selectivity or in oscillator applications that require very high stability. In addition, for many applications requiring only moderate sta-

bility, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators were used for many less demanding applications such as providing timing signals for watches, clocks, and microprocessors in industrial, automotive, and consumer products.

For very high frequencies (above 100 megahertz), the quartz wafer becomes too thin for practical use. At these higher frequencies, quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than wafer thickness, have become more important. These structures are called surface acoustical wave (SAW) devices.

Most optical applications used quartz in the fused form as silica glass. Relatively small quantities of cultured quartz crystal were used directly for special optical considerations. Quartz's crystal properties are responsible for its uses that deal with normally polarized laser beams. Quartz retardation plates (especially quartz wave plates), Brewster windows and prisms, birefringent filters, and tuning elements are used in laser optics.

Sand and lascaras were raw materials used by the majority of manufacturers in the silica glass industry. High-quality domestic silica sands were suitable for most uses, although lascaras may be used as a feedstock material for manufacturing special large lenses, mirrors, and windows.

Historically, quartz crystal has been a material of strategic importance. During World War II, quartz was used principally in analog communications (e.g., in telephone multiplexing and in mobile military radios). Today, because of military emphasis on command, control, and communications (C³) surveillance and the growth of more sophisticated electronic systems, the importance of use of quartz crystal devices has grown. Many of the military applications are at the leading edge of technology. It has been U.S. Department of Defense policy to require that all military systems be hardened to nuclear radiation. To meet this special requirement, cultured quartz crystal must be radiation hardened by sweeping, a technique to remove certain impurities from the quartz.

Because of cost advantages, cultured quartz was used almost exclusively by

the crystal device industry. For resonator applications, raw quartz must be cut into thin wafers oriented precisely with the raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural in the past have discontinued use of natural quartz. One of the remaining uses of natural electronic-grade material was in pressure transducers used in deep wells.

STOCKS

Crystal growers' stocks of as-grown cultured quartz crystal were reported as 56,000 kilograms at the beginning of 1989. At yearend, these stocks had increased to 73,000 kilograms.

PRICES

The average value of as-grown cultured quartz, based on reported sales of about 340,000 kilograms, was \$30.67 per kilogram (\$13.91 per pound), an increase of 59% compared with that of 1988. Sales volume increased 22%. The average value of lumbered quartz, as-grown quartz that has been processed by sawing and grinding, increased 17% to \$140.97 per kilogram (\$63.94 per pound), based on reported sales of 40,000 kilograms. Sales volume decreased 37%.

FOREIGN TRADE

The Bureau of the Census began using the Harmonized Tariff Schedule in 1989 to identify material passing through U.S. customs. This system makes classification codes for imports and exports consistent internationally. With the adoption of the new codes, imports and export codes for quartz crystal changed, and some formerly listed details are no longer available. The import code for Brazilian crude pebble, which represented nearly all

lascaras imports recorded, was eliminated. Although this material probably continued to enter the United States, the new code system aggregated several categories making information about specific materials unavailable. Likewise, the export data for natural electronic-grade quartz crystal were no longer available.

Because of these changes, foreign trade information for quartz crystal is limited. While information remained concerning exports of synthetic quartz crystal, comparison between the figures for 1988 and 1989 indicated that exports decreased nearly 70%. Reports for domestic producers indicated that these data may not be accurate. Reports indicated that exports were higher than those reported by Census.

OUTLOOK

Domestic production of cultured quartz crystal has grown steadily since 1986. Increased demand for crystal devices for electronic consumer products along with similar increases for all microprocessor controlled devices, indicated that quartz crystal production should remain strong well into the future. Because crystal devices continued to be used in an increasing variety of applications from kitchen appliances to military hardware in addition to the traditional items such as watches, demand should continue to increase and additional production capacity will be required worldwide.

¹National Materials Advisory Board. Quartz for the National Defense Stockpile. Natl. Acad. Sci., Washington, DC, NMAB-424, Jan. 1985, 99 pp.

²U.S. Senate. Title XXXIII—National Defense Stockpile, Sec. 3301. Authorized Changes in Material Quantities. Congr. Rec., v. 135, No. 110, Aug. 15, 1989, pp. 10507-10508.

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